Comparison of Gesture, Gamepad, and Gaze-based Locomotion for VR Worlds

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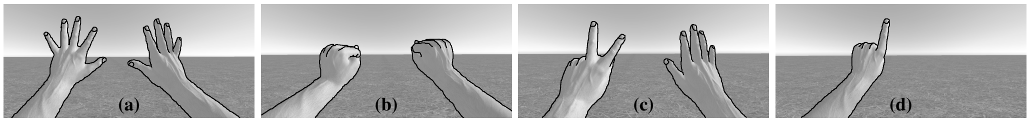

Figure 1: *Hand poses for the LMTravel technique.*

Abstract

In this paper we present a VR locomotion technique based on the Leap Motion device and compare it to other often-used locomotion techniques – gaze-directed locomotion and gamepad-based locomotion. We performed a user experiment to evaluate the three techniques based on their performance (time to complete the task), comfort (through the ISO 9241-9 assessment of comfort questionnaire), and simulation sickness (through the Simulation Sickness Questionnaire). Results indicate that the gamepad technique is both faster and more comfortable than either the Leap Motion-based or the gaze-directed techniques.

Keywords: Interaction Device, Leap Motion, HCI, Virtual Reality, Locomotion, Performance Measurement

Concepts: •**Human-centered computing** → **Virtual reality; Gestural input;** *Empirical studies in HCI;*

1 Introduction

The most common approach for locomotion in HMD-based VR still requires the usage of some sort of controller. Most often, users are standing, or sitting still, wearing a VR headset and navigate through the 3D world using a joystick, mouse, game controller, or other traditional controller. However, these controllers do not provide a very natural way for locomotion inside a 3D world because they impose an arbitrary mapping between the users actions (e.g. pressing buttons) and the virtual avatar movement inside the VR world. Additionally, these techniques require users to carry this controller at all times – when users drop or puts the device down, it may be hard to pick it up again without taking the headset off. Locomotion solutions based on treadmill-like hardware such as the Virtuix Omni (http://www.virtuix.com/), or Infinadeck (http://infinadeck.com/), are more expensive solutions and require additional setup and learning. Real walking solutions where users are free to walk inside a tracking room, require substantial infrastructure and are not available to the general consumer.

In this work, we define a gesture-based locomotion technique that uses the Leap Motion (LM) device and we perform an experimental evaluation and comparison with two other locomotion techniques – gamepad-based, and gaze-directed locomotion. We measured the time it took for participants to complete the tasks, and we also gathered subjective feedback through the Simulation Sickness Questionnaire (SSQ) [Kennedy et al. 1993] and the ISO 9241-9 assessment of comfort questionnaire [International Organization for Standardization 2000]

2 Locomotion Techniques

The Leap Motion locomotion technique (LMTravel) is designed for use with the Leap Motion controller mounted on the VR headset.

The LMTravel is based on hand gestures that allow us to control:

- Movement start/stop. Opening both hands starts the movement (Figure 1a); closing both hands stops the movement (Figure 1b).
- Movement speed. The number of fingers stretched defines the movement speed: one finger corresponds to the lowest speed; five fingers stretched corresponds to the highest speed (Figure 1c).
- Rotation. The tilt angle of the right hand is mapped to the rotation of the avatar.

The technique can also be used without rotation control by the right hand, using instead the rotation from the headset (i.e., the movement is directed by the users gaze). In this case, once the movement has started, the right hand can be lowered and speed can be controlled by the left hand (Figure 1d).

In the Gamepad technique users control the direction of movement using the gamepad's joystick button. We opted to allow movement in eight directions: the usual forward, backward, left strafe and right strafe directions, and the intermediate diagonal directions, as this is more inline with what gamepad users would expect from the controller. Again, the forward movement is relative to the users gaze.

The Gaze-based locomotion technique places a cursor in the center of the screen and a corresponding target icon (a white cylinder) in the floor in case the users gaze intersects the floor. By pressing a button (for implementation simplicity, we used a wireless mouse) the user moves to the target location. In the Gaze technique, the user is free to look anywhere while the travelling is in progress.

3 Experiment

The purpose of this study was to compare the efficiency and usability of the various travel techniques. For this, we created a simplified 3D environment with two main areas, where users were asked to

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perform two locomotion tasks in a first person 3D perspective. Task 1 was a simple path following task that took place in an open area composed of 7 circular platforms on the ground. The next platform that the user should get to was indicated by a large purple sphere in the air over the platform. Task 2 consisted in searching for a red vase inside each of the 8 houses in another area of the environment.

After both tasks were complete for a given interaction technique, we asked participants to remove the headset and fill in the SSQ and the ISO 9241-9 questionnaires. After the last travel technique experimented, we additionally asked the participant to fill in a two-question questionnaire where they would state which technique they liked best and which one they disliked the most.

The headset was an Oculus Rift DK2 and the computer that ran the VR world was an iMac capable of driving the Rift at 70 fps. The VR scenarios and logging software was programmed in Unity 3D. We used a Leap Motion device version 1.2.1+10992.

4 Results and Discussion

(Plots are available in the Auxiliary Material.) Looking only at the resulting trajectories (Plot 1) from the different techniques, we observe noticeable differences between them. With gaze-directed locomotion, trajectories are essentially straight lines (except in the cases where participants select a different target location before the current movement finishes), but participants often overshoot their targets. This may be due to the fact that the selection cursor of the gaze technique gets smaller as it is placed farther away from the user. Also, at higher distances, the same angular displacement of the head causes a higher linear displacement of the selection cursor, making it harder to position accurately. This issue might have been alleviated with a better visual feedback on the selected target position, e.g., by highlighting the objects on which the cursor rests. In terms of trajectory, the LMTravel results in fairly straight lines, indicating a that users have control over the trajectory. In fact, in task 1, the LMTravel technique resulted in the shortest average distance per sequence. The gamepad technique resulted in jagged trajectories. This may be due to inadvertent changes in direction (users may position the joystick a bit to the sides causing a side short movement) or simply because movement corrections have to be made in a discrete way. However, overall it did not result a substantially higher distance when compared to the LMTravel.

We measured how long participants took to complete each sequence in task 1 (Plot 2), and how long it took them to complete task 2. There seem to be an obvious learning effect for Gaze and LMTravel. It is also apparent that the Gamepad technique far exceeds the other in terms of movement performance. In the next comparisons, we have removed sequence number 1 from the data because the learning effect is most obvious for that sequence. The differences between the techniques in both task 1 and task 2 are very similar. There is a significant difference between Gamepad and both LMTravel and Gaze. Users are much faster with the gamepad, spending about 20% less time in either task, than with Gaze or LMTravel techniques.

Table 1: *Movement duration (seconds). Task 1 - average sequence duration. Task 2 - average time for completion.*

Task	Technique	Mean (95% conf. int.)	SD	Min	Max
Task 1	Gaze	51.2 (49.8, 52.6)	8.6	39.3	94.7
	LMTravel	48.2 (46.4, 50.1)	11.5	32.3	90.0
	Gamepad	40.1 (38.6, 41.6)	9.6	24.7	67.0
Task 2	Gaze	218.7 (202.0, 235.5)	47.5	148.0	339.4
	LMTravel	213.3 (203.2, 223.3)	28.6	164.2	274.4
	Gamepad	165.9 (153.0, 178.8)	37.2	116.5	259.8

In the ISO 9241-9 assessment of comfort questionnaire results (Plot 3), the Gaze and Gamepad techniques are rated very similarly by the participants of the study (Gaze is rated slightly lower than the Gamepad technique). The LMTravel technique however, scores negatively in various questions, specifically the arm fatigue, effort required for operation, general comfort, and shoulder fatigue items have been rated lower than 2.5, on average. These results agree with other assessments of the LM device in other situations: [Seixas et al. 2015] evaluated the LM device for desktop 2D pointing and the results of the ISO 9241-9 questionnaire also show low scores in these items. These results are expected as the LMTravel technique requires users to keep their arms lifted in order for them to be detected by the LM device. Without any physical support, the required position is not comfortable and after prolonged use results in fatigue – similar to the gorilla arm effect with prolonged use of vertical touch screens. The results from the SSQ (Plot 4) show slightly higher values for the Gaze technique than the Gamepad (with the LMTravel generally in between), however, the results are not statistically significant. We also asked participants to explicitely tell us which technique they liked best (Gamepad: 59%, LMTravel: 33%, Gaze: 8%) and which one they disliked most (Gamepad: 15%, LMTravel: 28%, Gaze: 56%[1]). Clearly, the Gamepad technique was the favorite: it was chosen as the preferred technique by almost 60% of the participants. The Gaze-directed technique was the least liked: chosen by 56%. The preference for the LMTravel technique was more divided: 33% chose it as the preferred technique, and 28% chose it as the least preferred technique.

5 Conclusion

The results indicate that the Leap Motion gestures we chose perform (movement speed) better than the Gaze technique but worst than the Gamepad technique. Also, results show that the effort required to operate the Leap Motion in these conditions is considerably higher than the effort required to operate the Gamepad or the Gaze-based techniques. In this study, we did not refine the LMTravel technique very much, as we wanted to get an initial feedback on the possibilities of the device for locomotion within VR. It is possible to conceive interaction techniques for the LM device that do not require users to keep their arms extended, hence reducing the effort of using the device. However, the current results are an indication that the LM-based techniques should not be used in situations of prolonged use. While the LMTravel technique is not as performant as the Gamepad technique, it is nonetheless worth considering in many situations. The LM device has the obvious advantage of not requiring users to hold a physical device, making their hands free to pick up physical objects.

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[1] Percentagens do not sum to 100 due to rounding.